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स्पंद तकनीकें और उपकरण

भाग 2 स्पंद मापन और विश्लेषण, सामान्य विचार

Indian Standard

PULSE TECHNIQUES AND APPARATUS

PART 2 PULSE MEASUREMENT AND ANALYSIS, GENERAL CONSIDERATIONS

ICS 33.120.10

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

June 1998 **Price Group 5**

Electronic Measuring Instruments, Systems and Accessories Sectional Committee, LTD 21

FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Electronic Measuring Instruments, Systems and Accessories Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

The objective of this standard is to standardize the definition of terms and the description of techniques and procedures which are applicable to the determination of the characteristics of practical and hypothetical pulses regardless of the applicable limits of error and to a wide range of technologies and disciplines.

This standard covers pulse measurement and analysis, general considerations. The Part 1 covers pulse terms and definitions.

This standard is largely based upon IEC Pub 469-2 (1987) 'Pulse techniques and apparatus: Part 2 Pulse measurement and analysis, general considerations', issued by the International Electrotechnical Commission.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

PULSE TECHNIQUES AND APPARATUS

PART 2 PULSE MEASUREMENT AND ANALYSIS, GENERAL CONSIDERATIONS

1 SCOPE

This standard provides definitions and descriptions of the techniques and procedures for time domain pulse measurements. The definitions and descriptions provided are independent of specific devices, apparatus, instruments or computing devices which may be used in pulse measurements and are necessary for:

- efficient communication of the results of pulse measurement,
- standards for pulse apparatus, and
- standards for apparatus which employ pulse techniques.

2 REFERENCE

The Indian Standard given below is a necessary adjunct to this standard:

IS No.	*Title*
IS 14501 (Part 1) : 1998	Pulse techniques and apparatus: Part 1 Pulse terms and definitions

3 DEFINITIONS

For the purpose of this standard, the definitions given in IS 14501 (Part 1) shall apply. in addition to the following.

3.1 Pulse Measurement Terms

The pulse measurement terms defined in this clause are applicable to measurement in general and are not defined in order to draw a distinction between pulse measurement and measurement in general.

3.1.1 *Pulse Measurement*

The assignment of a number and a unit of measurement to a characteristic, property or attribute of a pulse wherein the number and unit assigned indicate the magnitude of the characteristic which is associated with the pulse. Typically, this assignment is accomplished by comparison of a transform of the pulse (its pulse waveform) with a scale or reference which is calibrated in the unit of measurement.

3.1.2 *Method of Pulse Measurement*

A method of making a pulse measurement comprises:

- the complete specification of the functional characteristics of the devices, apparatus, instruments and auxiliary equipment to be used;
- the essential adjustments required;
- the procedures to be used in making essential adjustments;
- the operations to be performed and, their sequence;
- the corrections that will ordinarily need to be made;
- the procedures for making such corrections; and
- the conditions under which all operations are to be carried out.

3.1.3 *Pulse Measurement Process*

A realization of a method of pulse measurement in terms of specific devices, apparatus, instruments, auxiliary equipment, conditions, operators and observers.

3.1.4 *State of Statistical Control*

In a pulse measurement process, that state wherein a degree of consistency among repeated measurements of a characteristic, property or attribute is attained.

3.1.5 *Error*

The difference between the result of the application of a pulse measurement process and the true value of the characteristic, property or attribute being measured.

3.1.6 *Dispersion*

The degree of mutual disagreement among the results of independent measurements of a pulse characteristic, property or attribute yielded by repeated applications of a pulse measurement process.

3.1.7 *Resolution*

The smallest change in the pulse characteristic, property or attribute being measured which can unambiguously be discerned or detected in a pulse measurement process.

3.2 Statistical Terms

Statistical terms are given in IS 7920 (Part 1) 'Statistical vocabulary and symbols: Part 1 Probability and general statistical terms'.

3.3 Waveform Formats

Waveforms may exist, be recorded or stored in a variety of formats. Throughout this standard, it is assumed that:

- waveform formats are in terms of Cartesian co-ordinates or some transform thereof,
- conversion from one waveform format to any other is possible, and
- such waveform format conversions can be made with limits of error, dispersion and resolution which are consistent with the limits of error desired in the pulse measurement process.

3.3.1 *Pictorial Format*

A graph, plot or display in which a waveform is presented for observation and/or analysis. Any of the waveform formats defined in the following clauses may be presented in the pictorial format.

3.3.2 *Equational Format*

One or more algebraic equations which specify a waveform wherein, typically, a first equation specifies the waveform from t_0 to t_1, a second equation specifies the waveform from t_1 to t_2, etc. The equational format is typically used to specify hypothetical, ideal or reference waveforms.

3.3.3 *Sampled Format*

A waveform which is a series of sample magnitudes taken sequentially or non-sequentially as a function of time. It is assumed that non-sequential samples may be rearranged in time sequence to yield the following sampled formats.

3.3.3.1 *Periodically sampled real time format*

A finite sequence of magnitudes m_0, m_1, m_2,.....m_n each of which represents the magnitude of the wave at times t_0, $t_0+\Delta t$, $t_0+2\Delta t$, ..., $t_0+n\Delta t$, respectively, wherein the data may exist in a pictorial format or as a list of numbers.

3.3.3.2 *Periodically sampled equivalent time format*

A format which is identical to the periodically sampled real time format, except that the time coordinate is equivalent to and convertible to real time. Typically, each datum point is derived from a different measurement on a different wave in a sequence of waves.

3.3.3.3 *Aperiodically sampled real time format*

A format which is identical to the periodically sampled real time format, except that the sampling in real time is not periodic and wherein the data exist as co-ordinate point pairs, t_1, m_1; t_2,m_2; ....; $t_n m_n$.

3.3.3.4 *Aperiodically sampled equivalent time format*

A format which is identical to the aperiodically sampled real time format, except that the time coordinate is equivalent to and convertible to real time. Typically, each datum point is derived from a different measurement on a different wave in a sequence of waves.

3.4 Waveform Epoch Expansion and Contraction

3.4.1 *Waveform Epoch Expansion*

A technique for the determination of the characteristics of a transition waveform (or pulse waveform) wherein the transition waveform epoch (or pulse waveform epoch) is expanded in time to a pulse waveform epoch (or waveform epoch) for the determination of magnitude and/or time reference lines. The reference lines determined by analysis of the pulse waveform (or waveform) are transferred to the transition waveform (or pulse waveform) for the determination of characteristics (*see* Fig. 1).

In any waveform epoch expansion procedure, two or more sets of reference lines may exist, and the set of reference lines being used in any pulse measurement process shall be specified.

3.4.2 *Waveform Epoch Contraction*

A technique for the determination of the characteristics of individual pulse waveforms (or pulse waveform features) wherein the waveform epoch (or pulse waveform epoch) is contracted in time to a pulse waveform epoch (or transition waveform epoch) for the determination of time and/or magnitude characteristics (*see* Fig.1).

In any waveform epoch contraction procedure, two or more sets of time and/or magnitude reference lines may exist and the set of reference lines being used in any pulse measurement process shall be specified.

3.5 Reference Pulse Waveforms

A reference pulse waveform [*see* **2.4.1.3** and **2.8.1** of IS 14501 (Part 1)] may be specified by any of the waveform formats defined in **3.3**. The characteristics of the devices, apparatus, techniques, or algorithms used in producing or deriving a reference pulse waveform shall be specified.

3.5.1 *Defined Reference Pulse Waveform*

A reference pulse waveform which is defined without reference to any practical or derived pulse waveform. Typically, a defined reference pulse waveform is an ideal pulse waveform.

3.5.2 *Derived Reference Pulse Waveform*

A reference pulse waveform which is derived by a specified procedure or algorithm from the pulse waveform which is being analyzed in a pulse measurement process (*see* Fig. 2 for an example of a derived reference pulse waveform and its algorithm).

3.5.3 *Practical Reference Pulse Waveform*

A reference pulse waveform which is derived from a pulse which is produced by a device or apparatus.

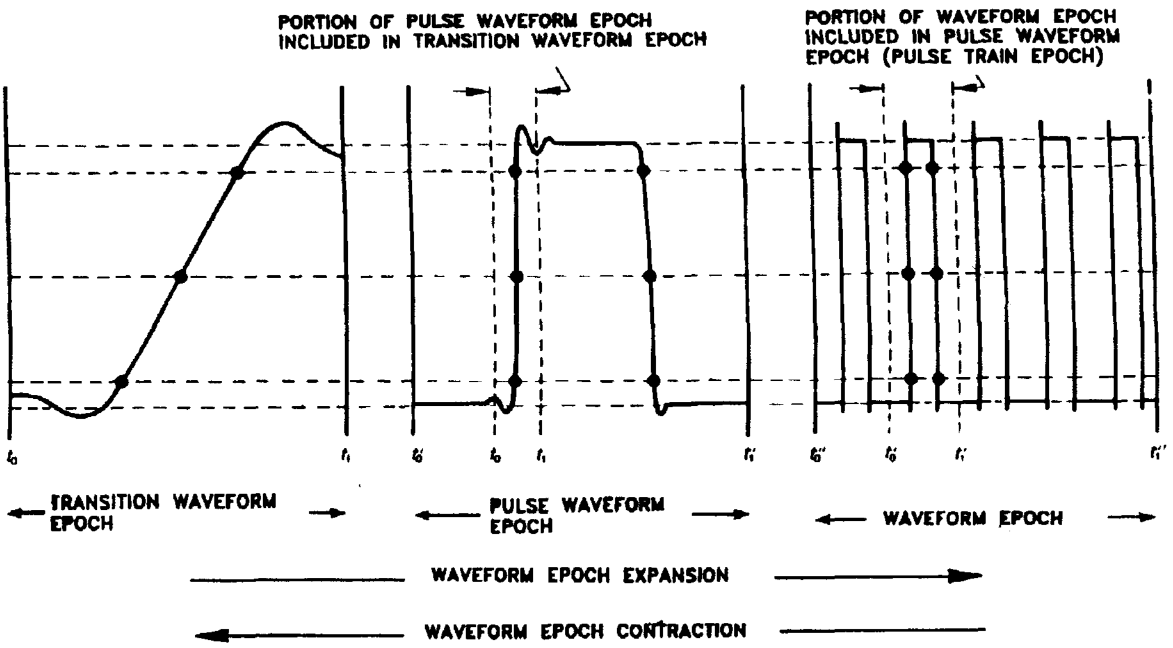
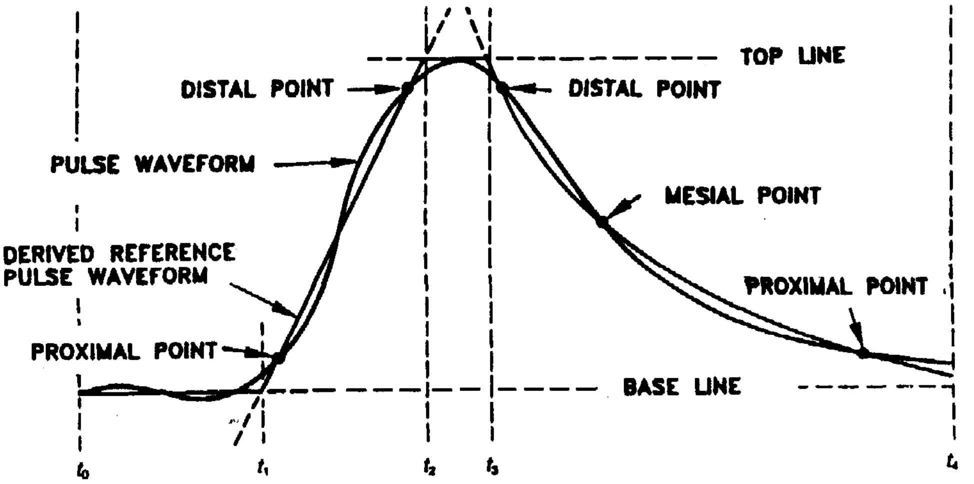

PORTION OF PULSE WAVEFORM EPOCH INCLUDED IN TRANSITION WAVEFORM EPOCH
PORTION OF WAVEFORM EPOCH INCLUDED IN PULSE WAVEFORM EPOCH (PULSE TRAIN EPOCH)
t_0
t_1
t_0'
t_0
t_1
t_1'
t_0''
t_0'
t_1'
t_1''
TRANSITION WAVEFORM EPOCH
PULSE WAVEFORM EPOCH
WAVEFORM EPOCH
WAVEFORM EPOCH EXPANSION
WAVEFORM EPOCH CONTRACTION

FIG. 1 WAVEFORM EPOCH EXPANSION AND CONTRACTION



NOTES

t_0-t_1 = Segment of the base line.

t_1-t_2 = Straight line through first transition proximal and distal points.

t_2-t_3 = Segment of the top line.

t_3-t_4 = Exponential curve through last transition proximal, mesial and distal points.

FIG. 2 DERIVED REFERENCE PULSE WAVEFORM

4 MEASUREMENT OF PULSE CHARACTERISTICS

4.1 The Distinction Between Waves and Waveforms

The distinction between waves, pulses and transitions and their respective waveforms is clearly drawn; the former are modifications of the physical state of a medium, or phenomena, while the latter are manifestations, representations, or visualizations of these phenomena [*see* **2.2** and **2.3.1** of IS 14501 (Part 1)].

NOTE — Throughout the remainder of this standard, the terms 'pulse' and 'pulse waveform' are used in the following inclusive sense:

a) 'Pulse' and 'pulse waveform' include 'transition' and 'transition waveform', respectively; and

b) In so far as is applicable, 'pulse' and 'pulse waveform' include 'wave' and 'waveform', respectively.

4.2 Description of the Pulse Measurement Process

The object of any pulse measurement process is the determination, within some limits of error, either expressed or implied, of the magnitude of a characteristic, property or attribute of a pulse. Figure 3 shows the constituent steps of any pulse measurement process where, as indicated, the process involves two distinct sequential sub-processes:

a) Pulse to pulse waveform conversion, and

b) Pulse waveform analysis.

Thus, the pulse measurement process involves:

- the conversion of a pulse into its transform, its pulse waveform;
- analysis of the pulse waveform to determine the magnitude of a pulse waveform characteristic,
- the assertion or assumption that the magnitude of the pulse waveform characteristic thus determined is, within some limits of error, identical to the magnitude of the pulse characteristic.

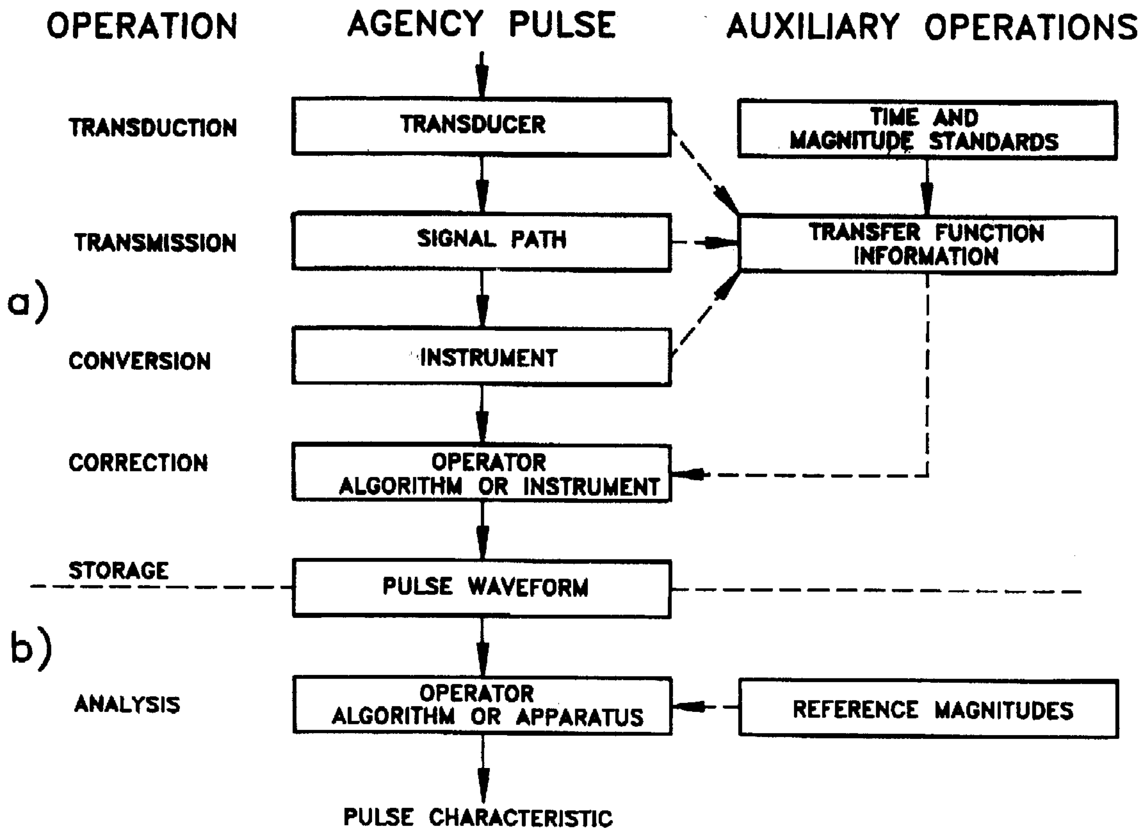
The validity of final assertion or assumption is dependent on the combined validity of the first two steps.

The vast array of devices, apparatus, instruments and techniques which may be configured in virtually limitless combinations to provide pulse to pulse waveform conversion renders the discussion of specific implementations beyond the scope of this standard. Such discussion is deferred to other standards, recommendations, documents or specifications which describe or define the characteristics or methods concerned with specific devices, apparatus, instruments or techniques.

A state of statistical control shall be achieved before a pulse measurement process can be considered to be a realization of a method of pulse measurement.

4.3 Pulse to Pulse Waveform Conversion

Item (a) of Fig. 3 shows the five basic operations — transduction, transmission, conversion, correction and storage — which, in some sense, are always present in pulse to pulse waveform conversion. The order in which these basic operations occur is not necessarily



a) = Pulse to pulse waveform conversion.
b) = Pulse waveform analysis.

FIG. 3 PULSE MEASUREMENT PROCESS

that shown in the figure and, frequently, an operation occurs more than once.

Three of the basic operations, transduction, transmission and conversion involve apparatus or devices whose transfer functions must be known to limits of error consistent with the overall limits of error desired in the pulse measurement process. The determination of transfer functions is indicated in item (a) of Fig. 3 by the broken lines leading to auxiliary operations. In these auxiliary operations, which may be other pulse measurement processes, the transfer functions of the apparatus are:

a) adjusted to predetermined values, that is, the apparatus is calibrated, or
b) determined and retained for subsequent use in the correction operation.

Item (a) of Fig. 3 also shows that the determination or adjustment of transfer functions entails comparison, either directly or indirectly, with basic or derived time and magnitude standards.

The following clauses describe each of the five operations which are present in pulse to pulse waveform conversion.

4.3.1 *Transduction*

Pulses propagate in numerous modes in gases, liquids, solids, in vacuum and in networks made up of such media. In transduction, a device or apparatus abstracts energy from the medium in which the pulse propagates and converts the energy to a form suitable for transmission.

4.3.2 *Transmission*

Transmission may occur over signal paths which utilize radiative, electrical, hydraulic, pneumatic or mechanical phenomena or analogue to digital or digital to analogue conversion techniques.

4.3.3 *Conversion*

Typically, the conversion operation involves an instrument which relates its input signal to real or equivalent time.

Such an instrument may provide a display of the relationship of the input signal to time. Such displays frequently function as the storage operation (*see* **4.3.5**). Display is not necessarily an attribute of the conversion operation.

4.3.4 *Correction*

The correction operation combines the results of the conversion operation with the transfer function information to yield a pulse waveform which is a more accurate transform of the pulse. Correction may be effected by: (a) a mental process by an operator, (b) a computational process, or (c) a compensating device or apparatus. Correction shall be performed with limits of error which are consistent with the overall limits of error desired in the pulse measurement process.

4.3.5 *Storage*

Storage is a transitional operation between pulse to pulse waveform conversion and pulse waveform analysis. Storage may be effected in numerous ways and display is not required, but the stored data must be available or retrievable for pulse waveform analysis. Typically, storage is effected in one of the waveform formats defined in **3.3**.

5 PULSE WAVEFORM ANALYSIS

5.1 Generality of Pulse Waveform Analysis

Pulse waveform analysis has broad utility since, when it is combined with waveform epoch expansion and contraction or applied to waveforms which are produced by operations on pulse waveforms [*see* **5.5.1** of IS 14501 (Part 1)], its principles and techniques apply to:

a) transition waveform analysis,
b) analysis of complex waveforms,
c) analysis of the constituent pulse waveforms of a pulse train or pulse burst, and
d) analysis of the top and base envelopes of a pulse burst.

and are necessary for:

i) analysis of the time relationships between different waveforms, and
ii) analysis of distortion, jitter and fluctuation.

5.2 Waveform Epoch Determination

5.2.1 *Selection of the Pulse Waveform Epoch*

A pulse waveform epoch [*see* **2.3.2** of IS 14501 (Part 1)] is the span of time for which waveform data are known or knowable and any analysis is based on the data within the epoch. These data may be augmented by reference lines which are determined by waveform epoch expansion or contraction. In any pulse measurement process, sufficient data shall be present to yield base and top magnitudes [*see* **3.2.1** and **3.2.2** of IS 14501 (Part 1)] which are consistent with the limits of error desired in the pulse measurement process.

5.2.2 *Exclusion of Data from Analysis*

Data in a pulse waveform epoch may be excluded from the analysis under certain conditions, for example:

- base magnitude may be determined solely from data which precede the first transition.
- a pulse waveform may include feature or events which are non-pertinent in the circumstances of or to the application of the

pulse. Non-pertinent data may be excluded from analysis. However, such exclusions may only be made on the basis of demonstrable information or knowledge.

When data within a pulse waveform epoch are excluded from analysis, the following shall be specified:

- the extent, in time/or magnitude, of the excluded data;
- the demonstrable information or knowledge which justifies the exclusion; and
- whether the excluded data are ignored (that is, the waveform which is analyzed is discontinuous) or replaced (that is the excluded data are replaced with other assumed or derived data).

5.3 Analysis of the Single-Pulse Waveform

Pulse waveform analysis may be effected by:

a) a mental process by an operator,
b) a computational process, or
c) an apparatus or instrument.

In all cases, the pulse waveform is operated upon by the analyzing algorithm(s) and the same principles apply regardless of the pulse waveform format or the analyzing agency. Throughout this clause, it is assumed that the analysis is performed by a computing device since this method:

a) is the most general,
b) is potentially the most accurate, and
c) fully illustrates the operations which an operator or apparatus shall, in some sense and to some limits of error, perform.

The analysis of the single pulse waveform requires the sequential determination of the:

- base magnitude and top magnitude;
- pulse amplitude;
- proximal, mesial, and distal lines and points; and
- magnitudes of all other pulse waveform characteristics expressed as computed differences between line and/or point pairs.

Typically, each of the above determinations is a necessity for the succeeding determination. Thus, algorithms for the determination of base magnitude, top magnitude and pulse amplitude only are described below since the determination of all other pulse waveform characteristics proceeds directly from these determinations [*see* **3** of IS 14501 (Part 1)].

5.3.1 *Base and Top Magnitude Algorithms*

In the following clauses, algorithms for determining base magnitude and top magnitude are described together. There is, however, no requirement to use the same algorithm for both determinations.

5.3.1.1 *Mean of density distribution*

The algorithm is based on determinations of the means of the occurrence density distribution of a pulse waveform. A graphical description follows:

a) Assume that a pulse waveform, such as that shown in Item a) of Fig. 4 has a superimposed rectangular grid in which each elementary rectangle has dimensions Δt and Δm.

b) Develop the occurrence density histogram as follows:
   i) For each horizontal element, of width *m*, count the number of elementary rectangles through which the pulse waveform passes.
   ii) At the magnitude corresponding to the location of the horizontal element, draw a histogram element whose length is proportional to the count in Item (a). This procedure yields the truncated bimodal histogram of Item b) of Fig. 4, in which P_B, the base histogram, and P_T, the top histogram, are identified.

c) Consider the histograms P_B and P_T separately and calculate the magnitudes (on the magnitude axis) of the means of P_B and P_T and take the magnitudes of these means as the base line magnitude and the top line magnitude, respectively.

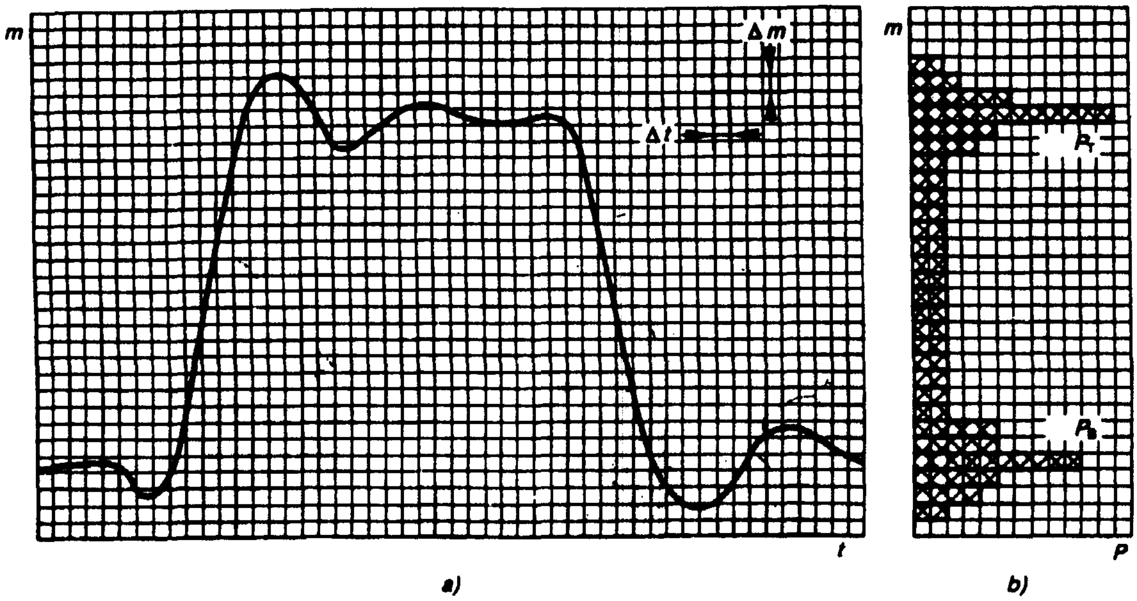
This algorithm is best suited to the analysis of pulse waveform with bases and tops of significant relative duration when the smallest error in the analysis is desired.

A graphical solution yields crude results, but as Δt and Δm become smaller, numerical calculation of the magnitudes of the means of the P_B and P_T yields more refined measures of the base line magnitude and top line magnitude respectively.

5.3.1.2 *Mode of the density distribution*

This algorithm is based on determinations of the modes of the occurrence density distribution of a pulse waveform and is identical to the algorithm described in **5.3.1.1** above, except for **5.3.1.1** (c).

This algorithm is best suited to the analysis of pulse waveforms with bases and tops of significant relative duration when results which are compatible with visual observation and mental analysis by an operator are desired.



a) Pulse waveform with superimposed grid
b) Probability density histogram

FIG. 4 GRAPHICAL DETERMINATION OF OCCURRENCE DENSITY

5.3.1.3 *Peak magnitude*

Determine the positive peak and negative peak magnitudes of the pulse waveform:

a) take the positive peak magnitude as the top (base) magnitude of a positive (negative) pulse waveform, and
b) take the negative peak magnitude as the base (top) magnitude of a positive (negative) pulse waveform.

This algorithm is best suited to the analysis of pulse waveforms with bases (tops) of negligible or relatively short duration.

5.3.1.4 *First (last) base point*

Determine the magnitude of the first (last) base point [*see* **3.3.5.2** of IS 14501 (Part 1)]. Take the magnitude of the first (last) base point as the base magnitude.

5.3.2 *Pulse Amplitude Algorithms*

5.3.2.1 *Determination of pulse amplitude by the integral technique*

Pulse amplitude is the algebraic difference between the top magnitude and the base magnitude [*see* **3.2.3** of IS 14501 (Part 1)]. Where the absolute magnitude of the base (or top) magnitude is either immaterial in a pulse waveform analysis or known from other measurements, the determination of pulse amplitude is sufficient.

Figure 5 illustrates the determination of pulse amplitude by the integral technique wherein the pulse waveform $e_u(t)$, whose pulse amplitude is unknown, and a practical reference pulse waveform $e_t(t)$ are alternately delivered to an instrument:

- — which has an input impedance of R ohms,
- — which can perform the integrations shown in equations (1) and (2), below, and
- — which indicates when the equalities specified in equations (1) and (2) are satisfied.

$$\int_{t_{u1}}^{t_{u2}} e_u(t)\ dt = \int_{t_{r1}}^{t_{r2}} e_r(t)\ dt \qquad \dots (1)$$

$$(1/R) \int_{t_{u1}}^{t_{u2}} [t\, e_u(t)]^2\ dt = (1/R) \int_{t_{r1}}^{t_{r2}} [e_r(t)]^2\ dt \quad \dots (2)$$

when the equalities are satisfied, the pulse amplitude of the unknown pulse waveform, $e_u(t)$, is taken as equal to the pulse amplitude of the practical reference waveform, $e_r(t)$. It is not necessary to evaluate the integrals of $e_u(t)$ and $e_r(t)$ between identical limits; in fact, as is indicated for $e_u(t)$ in Fig. 5 it is preferable to adjust the extent of the integration(s) so that distortions which precede and follow the pulse waveform(s) do not contribute to the integral(s).

This algorithm is best suited to analysis in which an unknown pulse waveform and a practical reference pulse waveform with very nearly identical pulse shapes are compared.

A reference pulse waveform may be specified by any of the waveform formats defined in **3.3**. The charac-

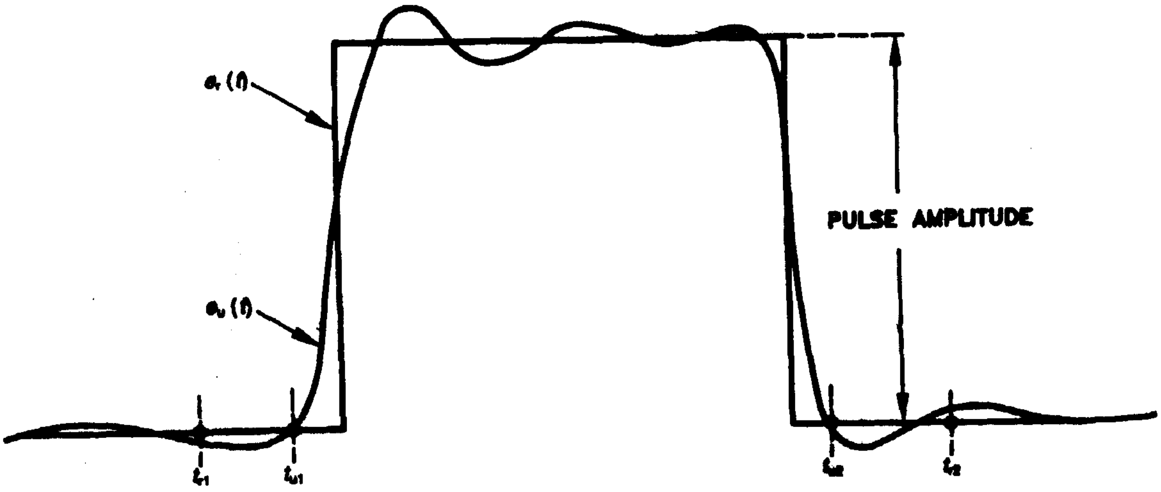


FIG. 5 DETERMINATION OF PULSE AMPLITUDE BY THE INTEGRAL TECHNIQUE

teristics of the devices, apparatus, techniques or algorithms used in producing or deriving a reference pulse waveform shall be specified.

5.3.3 *Determination of the Other Pulse Characteristics*

When (a) the base magnitude and top magnitude, or (b) the base magnitude and pulse amplitude of a pulse waveform have been determined, the determination of all other pulse characteristics follows directly from existing definitions of:

a) proximal, mesial, and distal lines and points [*see* **3.2.5** and **3.2.6** of IS 14501 (Part 1)].
b) the magnitudes of all other pulse waveform characteristics as computed differences between line and/or point pairs [*see* **3.3** of IS 14501 (Part 1)].

6 ANALYSIS OF TRANSITION WAVEFORMS

Transition waveform analysis is a special of pulse waveform analysis in which the analysis is made on a specified transition waveform of a pulse waveform. Waveform epoch expansion may be used to establish the time and magnitude reference lines required in a transition waveform analysis.

7 ANALYSIS OF COMPLEX WAVEFORMS

Typically, the analysis of complex waveforms involves:

- decomposition of the complex waveform into more elementary constituent pulse waveforms, or
- conversion of a multiplicity of constituent elements into pulse waveforms.
- In any analysis of complex waveforms, the algorithms or procedures used in decomposition or conversion shall be specified.

7.1 Analysis of Combinations of Pulses and Transitions

Double pulse, bipolar pulse or staircase waveforms [*see* **5.1** of IS 14501 (Part 1)] may be analyzed by decomposing the waveform into constituent pulse and transition waveforms. Typically, the decomposition is effected by subdividing the waveform at specified time reference points.

7.2 Analysis of Waveforms Produced by Magnitude Superposition

Offset or composite waveforms [*see* **5.2** of IS 14501 (Part 1)] may be analyzed by decomposing the waveform into its constituent constant, pulse waveforms and transition waveforms. Typically, the decomposition is effected by a process which is the inverse of magnitude superposition.

7.3 Analysis of Waveforms Produced by Pulse Trains

The constituent pulse waveforms of a pulse train [*see* **5.3.1** of IS 14501 (Part 1)] may be analyzed by decomposition. Typically, the decomposition is effected by sub-dividing the pulse train into pulse train epochs [*see* **5.3.2.8** of IS 14501 (Part 1)] each of which includes a single constituent pulse waveform.

7.4 Analysis of Waveforms Produced by Pulse Bursts

The constituent pulse waveforms of a pulse burst [*see* **5.4.1** of IS 14501 (Part 1)] may be analyzed in a manner identical to that described in **7.3**.

The overall characteristics of a pulse burst may be analyzed by conversion of the pulse burst into its pulse burst top envelope and pulse burst base envelope [*see* **5.5.2** and **5.5.3** of IS 14501 (Part 1)]. These envelopes are then analyzed as single pulse waveforms.

8 ANALYSIS OF TIME RELATIONSHIPS BETWEEN DIFFERENT WAVEFORMS

The time relationships between different waveforms may be analyzed by:

a) applying the methods described in **5**, **6** and **7** in the analysis of the different waveforms, and
b) determining the time relationship between different waveforms [*see* **6** of IS 14501 (Part 1)] as computed intervals or durations.

9 ANALYSIS OF PULSE WAVEFORM DISTORTION

Pulse waveform distortion and pulse waveform feature distortion entail the determination of the differences between a pulse:

— waveform and a reference pulse waveform [*see* **7.1** of IS 14501 (Part 1)]. In any distortion determination, the type of reference pulse waveform, which may be any of the types defined in **3.5**, shall be specified.

When the reference pulse waveform is a practical reference pulse waveform or a defined reference pulse waveform, it shall be properly located, in time and magnitude, relative to the pulse waveform being analyzed. When the reference pulse waveform is a derived reference pulse waveform, its location relative to the waveform being analyzed is fixed by definition and shall not be altered.

10 ANALYSIS OF JITTER AND FLUCTUATION

The measurement of jitter only or fluctuation only in the substantial absence of the other is, typically, a relatively straightforward process. When, however, jitter and fluctuation are both present in significant amounts, these components shall be separated. Typically, separation is accomplished by first measuring fluctuation at points of zero waveform slope and subsequently applying the known fluctuation as a correction in the determination of jitter.

10.1 Analysis of Jitter

The analysis of jitter involves:

a) the repeated determination of a time characteristic of the constituent pulse waveforms in a pulse train, and
b) the determination of the instability of the measured time characteristic with respect to a reference time, interval or duration [*see* **7.3.1** of IS 14501 (Part 1)].

Jitter analysis thus involves the application of the methods of measurement described in **5**, **6**, **7** and **8** as required to a multiplicity of the constituent pulse waveforms in a pulse train.

10.2 Analysis of Fluctuation

The analysis of fluctuation involves:

a) the repeated determination of a magnitude characteristic of the constituent pulse waveforms in a pulse train, and
b) the determination of the instability of the measured magnitude characteristic with respect to a reference magnitude characteristic [*see* **7.3.2** of IS 14501 (Part 1)].

Fluctuation analysis thus involves the application of the methods of measurement described in **5**, **6**, **7** and **8**, as required, to a multiplicity of the constituent pulse waveforms in a pulse train.

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This Indian Standard has been developed from Doc: No. LTD 21 (1431).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Simco Printing Press, Delhi, India